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Biogas Potentiality of Agro-wastes Jatropha Fruit Coat

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***Abstract*—**The present investigation was undertaken to explore the biogas potentiality of Jatropha (*Jatropha curcas*, Euphorbiaceae) Fruit Coat (JFC) alone and in combination with cattle dung (CD) in various proportions at 15 per cent total solids by batch phase anaerobic digestion for a period of ten weeks HRT (Hydraulic Retention Time) under a temperature of 35°C±1°C. The maximum biogas production was noticed in Cattle dung and Jatropha Fruit Coat in 2:1 ratio with 403.84 L/kg dry matter followed by 3:1,1:2, 1:1 and 1:3 having 329.66, 219.77, 217.79, 203.64 L /kg dm respectively as compared to 178.49 L/kg dm in CD alone. The JFC alone found to produce 91 per cent of total biogas that obtained from Cattle dung. The per cent methane content of the biogas in all the treatments was found on par with Cattle dung.

***Keywords*—**Jatropha Fruit Coat, Cattle dung, Hydraulic Retention Time, Dry matter

I. Introduction

METHANE production from biomass is an interesting option for increasing the energy independence and efficient waste management. The animal wastes with their relatively low carbon to nitrogen ratios, improved for digestion purposes by adding cellulosic wastes such as crop residues, grasses, straw, etc beside feed density [1]. The knowledge on the conversion of substrates other than the traditionally used cattle dung for biogas production is insufficient [2]. *Jatropha curcas,* a member of the Euphorbiaceae family is gaining momentum now-a-days as a biofuel crop. The Physic nut yield around 0.5 to 12 tons of seeds/ hectare/year depending on soil and rainfall conditions [3]. The aim of the present paper is to evaluate the potential of JFC mixed with Cattle dung in various proportions for biogas production.

II. Materials And Methods

A. Feedstocks

JFC was collected from the jatropha plantation under the Division of Environmental Sciences of IARI, New Delhi. To increase the area for the action of anaerobic microorganisms, fruit coat was chopped into six equal parts. The Cattle dung was collected from Todapur Village, New Delhi. The chemical composition of JFC and Cattle dung is given in Table I.

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TABLE I
CHEMICAL COMPOSITION OF JFC AND CATTLEDUNG

Component	Cattle dung (% dry wt)	Jatropha fruit coat (% dry wt)
Cellulose	21.55	13.11
Hemicellulose	37.21	7.69
Lignin	20.38	28.91
Water Soluble matter	23.93	38.13
Soluble sugars	1.31	1.70
Starch	1.08	2.17
Crude Protein	15.57	21.87
Organic Carbon	24.82	32.52
Nitrogen	1.24	3.64
C:N ratio	20.02	8.93

B. Experimental Set Up

Seven treatments in three replications were taken for the study. The treatment, T1 contained JFC alone and the subsequent treatments consisted of cattle dung and Jatropha fruit coat in 1:3, 1:2, 1:1, 2:1 and 3:1 for T2, T3, T4, T5 and T6 respectively. T7 with Cattle dung alone was taken as the control. The experiment was carried out with 15 % Total solids. The composition of different treatments for anaerobic digestion was given in Table II.

The experiment was conducted during November to February and the temperature was kept constant around 35 ±1°C for optimization of the biogas yield as cited by [4] and [5].

C. Inoculum

The inoculum used to seed the anaerobic digestion of JFC and CD was prepared by composting the fresh cattledung under anaerobic condition for a period of five days in ambient temperature. The fresh cattledung contained active micro organisms. A pinch of urea was added taken in various treatments to supplement the nutrients so that it enhanced the growth and multiplication of the consortium of micro organisms. The inoculum was added to the substrates of each treatment at 5% v/v i.e. 50 ml per liter slurry.

D. Anaerobic Batch Digestion assembly

Laboratory studies were conducted by using 2 L capacity conical flasks, with a provision to draw the biogas samples (Fig. 1), as batch digesters for carrying out the anaerobic digestion. The feed stocks were diluted with the requisite amount of water so as to make 15 per cent total solid concentration. The gas generated was collected in inverted calibrated gas collection jar filled with water which was partly immersed in water bath.

TABLE II
COMPOSITION OF CATTLE DUNG AND JFC TAKEN IN VARIOUS TREATMENTS

Treatments	Weight of the substrate			Volume of additive		Total volume of slurry (ml)
	CD(g)	JFC (g)	CD + JFC (g)	Inoculum (ml)	Water (ml)	
JFC alone	0	171.43	171.43	50	778.57	1000
CD+JFC(1:3)	187.5	128.57	316.07	50	633.93	1000
CD+JFC(1:2)	250.0	114.29	364.29	50	585.71	1000
CD+JFC(1:1)	375.0	85.71	460.71	50	489.29	1000
CD+JFC(2:1)	500.0	57.14	557.14	50	392.86	1000
CD+JFC(3:1)	562.5	42.86	605.36	50	344.64	1000
CD alone	750.0	0	750.00	50	200.00	1000

Fig. 1 Experimental set up for biogas production

E. *Quantification of Biogas*

The biogas produced from anaerobic digestion of Jatropha Fruit Coat and cattle dung was estimated by water displacement method [6].

F. *Analysis of Biogas*

The methane content in biogas samples was quantitatively analyzed by gas chromatographic method [7]. The samples of biogas were analyzed using Gas Chromatograph (GC 2014 series chromatograph Schimadzu) fitted with Forward tract ionization Detector (FTD) and SPB-1 (cross linked methyl silicon) column. The capillary column is used with a length of 30 m which is made of fused silica with a polyamide coating. The carrier gas contained He (0.8 kg/cm^2), air(0.45 kg/cm^2) and Hydrogen (0.6 kg/cm^2). Column, injector and detector temperature were kept at 150–250^{O}C, 250^{O}C, 270^{O}C respectively. The area under the peak was measured by means of a microprocessor based integrator (Schimadzu GC 2014 series) attached to the chromatograph.

G. *Estimation of Volatile Solids, Organic Carbon, Nitrogen, Cellulose, Hemicellulose and Lignin*

Volatile solid percentage was determined in a muffle furnace at 580^{O}C ± 5^{O}C [8]. Total nitrogen in the sample was estimated by Kjeldhal method and expressed as percentage on dry weight basis [9]. Organic carbon was determined by Walkley and Black [10] method which was described by Jackson [11].

The substrates and biogas spent sludge were analyzed for cellulose, hemi cellulose and lignin [12] before and after digestion using 2022 Foss Tecator Fibertec Analyzer (following Foss Tecator application note, AN 380).

H. *Hydraulic Retention Period*

The optimum period for the economical gas production in batch fermentation depends largely on pattern of daily gas production and the pattern of changes in the calorific value of gas produced i.e. CH_4 content. The study period in the experiment was seventy days.

İ. *Statistical Analysis*

Data was assessed by analysis of variance (ANOVA).

III. RESULTS

A. *Quantitative Analysis of Biogas Yield*

Cumulative yields of biogas (expressed in litres/kg of dry matter) from JFC and its admixtures with cattle dung and the trends in biogas production are shown in Table III and Fig. 2 respectively.

TABLE III
PERIODIC AND TOTAL YIELDS OF BIOGAS OBTAINED FROM JATROPHA FRUIT COAT AND ADMIXTURES WITH CATTLEDUNG (L/ KG AT DRY WEIGHT)

Period (weeks)	JFC alone	CD:JFC (1:3)	CD:JFC (1:2)	CD:JFC (1:1)	CD:JFC (2:1)	CD:JFC (3:1)	CD alone
I	14.77	16.66	31.11	26.05	18.91	37.97	7.47
II	76.21	18.88	39.89	33.43	22.38	40.91	11.02
III	71.54	18.88	38.06	33.14	23.69	41.76	15.29
IV		18.66	37.33	31.69	24.05	41.76	23.82
V		20.32	36.78	31.40	28.12	41.76	30.76
VI		23.10	36.6	31.11	38.29	41.76	30.22
VII		26.38		30.97	48.10	41.87	30.04
VIII		29.71			58.75	41.87	
IX		31.05			68.2	41.76	
X					73.35		
Total	162.52	203.64	219.77	217.79	403.84	329.66	178.49

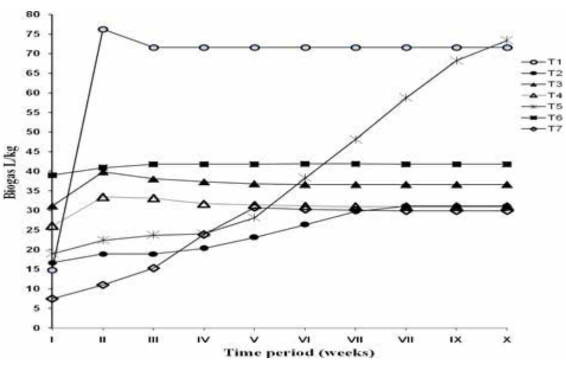

Fig. 2 Trend in Biogas production from different treatments of Cattle dung and Jatropha Fruit Coat

The rate of biogas production from JFC was observed to be rapid as compared to cattle dung during the second week of fermentation. With the progress of fermentation, the rate of production in the mixtures of Cattle dung and JFC increased substantially and biogas yield was faster than that from treatment with cattle dung alone. JFC alone produced biogas of 76.21 L /kg dm within 14 days and thereafter its production attained steady pace. The trend pointed out a gradual increase to a maximum between 14 and 21 days, then the gas production is maintained at a high level to the end of the experiment [13]. The total period taken for digestion was 70 days, beyond which the gas yield were more or less stopped as observed for all the treatments except CD: JFC in 2:1.

But the treatment, CD: JFC in 2:1 ratio showed a steady increase in biogas generation throughout the study period and yielded the highest amount of biogas i.e. 403.84 L/kg dry matter followed by CD: JFC in 3:1, generating 329.66 L /kg dm. All the treatments except treatment with Jatropha Fruit Coat alone have shown biogas potential higher than cattle dung and produced 203.64 , and 219.77 and 217.79 L/kg dm of biogas by CD: JFC in 1:3, 1:2 and 1:1 respectively compared to 178.49 L / kg from cattle dung. This higher yield may be due to the synergistic action of micro organisms from the co digestion process. This type of higher methane yield was observed by many researchers [14], [15] using different substrates as feedstock. The weekly gas yield records revealed that for the production of about 70 per cent of the total gas, the treatment with cattle dung alone had taken around 35 days [16[, [17].

The gas production results suggested that the Jatropha fruit coat alone has 90 per cent biogas production potential to conventional cattle dung. This also recorded a faster rate of high amount of gas production at a shorter retention period of 14 to 17 days than that of CD: JFC in 2:1 which had taken a longer retention time of 70 days.

It was observed that the biogas production from CD: JFC in 2:1 was continued for a period of 120 days but at a lower rate. The yield of biogas obtained during the 70 days study period amounted to about more than 80 percent of the total gas. The supplemented treatments had taken more time than cattle dung alone for complete biodegradation due to its difference in its physico-chemical characteristics due to various proportions of cattle dung and JFC.

The biogas yield results indicated that the processes of biogas generation from a mixture of animal manure with carbonaceous substrate proceeds better than that of animal manure alone and this is in agreement with that reported by [18], [19] as biogas production from swine manure supplemented with corn stalks was enhanced in excess 50% than non supplemented manure.

B. Qualitative analysis of Biogas

It was observed that methane content in the mixtures were more or less similar to that of conventional Cattle dung which is in agreement with [16],[20]. The weight ratio of JFC to total feedstock and its methane content are given in Table IV. The weight ratio of feed stocks, states that there is reduction in cattle dung, which is supplemented by Jatropha Fruit Coat is a solution for the non availability of cattle dung for biogas production. It was observed that in the initial period the percentage of methane was fairly low. Once a higher percentage of methane was reached it remains constant to the end of the experiment [21]. This is attributed to the dominance of carbohydrates material in JFC at the expense of proteins and lipids which have been reported to be essential precursors to methane [22]. The less significance in methane content among various treatments are due to the similar basic composition of biomass i.e. cattle dung and JFC.

TABLE IV
WEIGHT RATIO OF JFC TO TOTAL FEEDSTOCK AND ITS METHANE CONTENT

Treatments	Weight of the substrate				Biogas yield (l/kg dm)	Methane Content (%)
	CD (g)	JFC (g)	CD + JFC (g)	Weight ratio of JFC to total substrate		
JFC alone	0	171.43	171.43	1.0	162.52	57.2
CD+JFC(1:3)	187.5	128.57	316.07	0.41	203.64	56.2
CD+JFC(1:2)	250.0	114.29	364.29	0.31	219.77	57.8
CD+JFC(1:1)	375.0	85.71	460.71	0.19	217.79	56.6
CD+JFC(2:1)	500.0	57.14	557.14	0.10	403.84	58.3
CD+JFC(3:1)	562.5	42.86	605.36	0.07	329.66	58.5
CD alone	750.0	-	750.00	-	178.49	55.0

TABLE V
FIBER CHARACTERISTICS OF TREATMENTS BEFORE AND AFTER ANAEROBIC DIGESTION

Treatments	Volatile Solids (%)			Cellulose (%)			Hemi cellulose (%)			Lignin (%)		
	BD	AD	% loss after digestion	BD	AD	% loss after digestion	BD	AD	% loss after digestion	BD	AD	% loss after digestion
JFC alone	86.50	82.13	5.05	13.11	5.40	58.81	7.69	18.01	-134.2	28.91	41.97	-45.17
CD+JFC(1:3)	91.79	85.67	6.67	15.22	6.21	59.20	15.08	19.50	-29.31	26.78	38.98	-45.55
CD+JFC(1:2)	92.27	85.83	6.98	15.92	7.64	52.01	17.54	21.52	-22.69	26.07	32.92	-26.27
CD+JFC(1:1)	92.56	87.31	5.60	17.33	9.85	43.16	22.45	20.49	8.73	24.65	31.35	-27.18
CD+JFC(2:1)	91.29	83.76	8.25	18.74	6.46	65.53	27.37	25.03	8.55	23.22	34.58	-48.92
CD+JFC(3:1)	91.59	84.55	7.69	19.44	5.52	71.60	29.83	16.37	45.12	22.51	31.08	-38.07
CD alone	92.77	77.61	16.34	21.55	2.43	88.72	37.21	9.4	74.73	20.38	36.06	-76.93
SE $\pm$(m)	0.96	2.82	-	0.17	0.08	-	0.08	0.08	-	0.37	2.44	-
CD at 5%	1.71	2.92	-	0.72	3.29	-	1.05	2.72	-	0.49	2.65	-

TABLE VI
C: N RATIO AND CRUDE PROTEIN CONTENT OF VARIOUS TREATMENTS BEFORE AND AFTER ANAEROBIC DIGESTION

Treatments	Organic Carbon (%)		Nitrogen (%)		C:N ratio		Crude Protein	
	BD	AD	BD	AD	BD	AD	BD	AD
JFC alone	32.52	31.76	3.64	4.3	8.93	7.39	21.87	26.61
CD+JFC(1:3)	30.72	30.14	2.67	3.13	11.51	9.62	16.05	19.00
CD+JFC(1:2)	30.88	28.57	2.85	3.37	10.84	8.48	16.49	20.25
CD+JFC(1:1)	31.01	30.85	2.76	3.50	11.24	8.80	16.99	21.04
CD+JFC(2:1)	30.58	30.29	2.83	4.08	10.81	7.42	17.01	24.76
CD+JFC(3:1)	30.73	30.42	2.59	3.26	11.86	9.33	15.13	19.98
CD alone	24.82	16.56	1.24	1.72	20.02	9.68	15.57	18.01
SE ± (m)	1.59	1.58	0.08	0.08	-	-	-	-
CD at 5%	2.19	2.19	0.50	0.50	-	-	-	-

BD: Before digestion; AD: After digestion

The chemical composition of the substrates before digestion and those of the biogas spent sludge after fermentation in terms of fiber content such as cellulose, hemi-cellulose, lignin, etc was analyzed and presented in Table V.

The lignin content of JFC (28.9%) is more than that of the cattledung (20.38%) while cellulose and hemi cellulose in JFC (13.11 per cent and 7.69 per cent respectively) are lower than cattle dung, so possibly a greater percentage of carbon may be available to the bacteria from the cattle dung only. For digester feeds of Jatropha Fruit Coat and cattle dung, increasing quantities of JFC (contain greater amounts of lignin) produced less decrease in cellulose.

The increase in lignin content was higher than that of cellulose plus hemi cellulose content after digestion which showed that lignin degrade more slowly than the whole organic material as a whole [23]. The similar effect of lignin in biogas production was observed by [24].

Table V pointed out that the per cent loss after digestion is highest for cellulose and negative value of lignin and hemicellulose showed that there was an increase in its content. While lignin content increase is due to reduction of cellulose and other components of the feedstock [25]. The treatment with CD: JFC in 3:1 showed maximum cellulose degradation of 71.6 per cent followed by CD: JFC in 2:1 with 65.53 per cent which confirm the production of high biogas yield. Similar high cellulose degradation compared to hemi cellulose has also been noticed by [26]. Similarly JFC alone has low cellulose content than its admixtures after digestion.

It was noticed that there was an increment in nitrogen and crude protein content after anaerobic digestion. This was further supported by [21], [27], [28]. Table VI shows there is a decline in C: N ratio after anaerobic digestion. The composition of fermented substrate conversion of biodegradable carbon in biogas resulted in this decrease in C: N ratio in the biogas slurry [29].

IV. CONCLUSION

The supplementation of JFC to cattle dung up to 75 per cent can be advantageously used for the economic biogas generation from a total solid concentration of 15 per cent. This shows that the mixing of these two materials in different proportions enhanced the gas production by utilizing more of the complex substrates than when used alone. The effect may be due to the synergistic action of a variety of cellulolytic and hydrolytic bacterial species in the break down of raw materials [24]. The decline in gas production in treatment with JFC alone may be due to high lignin content. It is worth mentioning that slurry made of 2:1 Cattle dung and Jatropha fruit Coat was found the best among the various treatments in biogas generation. The admixtures of Cattle dung and JFC is a viable option for the energy production and for efficient management of Jatropha fruit coat which was otherwise creates environmental problems.

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